

Soiling in CSP: modeling and forecasting from weather inputs

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Knowledge for Tomorrow

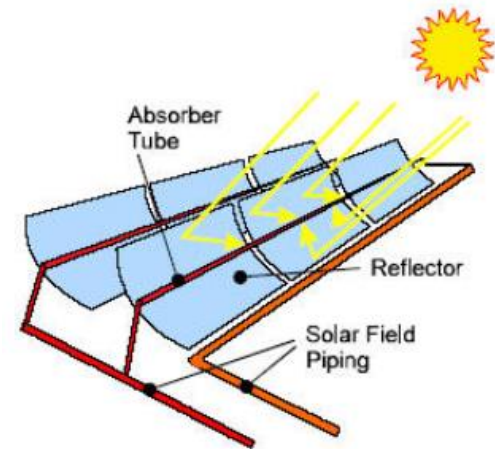
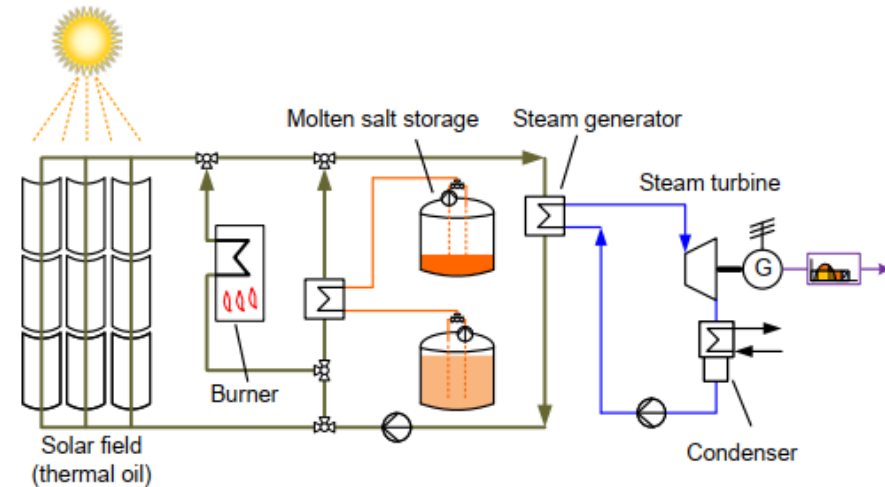


Outline

- Intro and short summary of PV-CSP-soiling comparison
- Measurements and sites
- Empirical soiling model: architecture, training and validation
- Soiling rate forecasting with dust transport models
- Summary and outlook



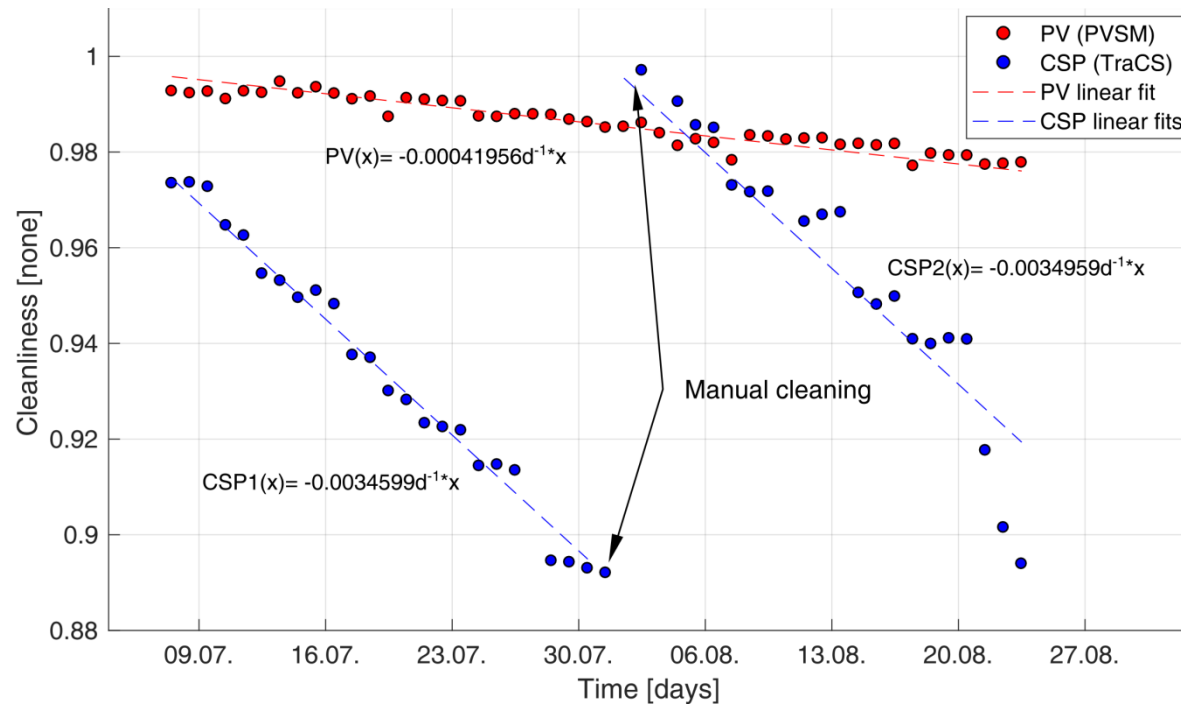
Concentrating Solar Power



- Concentration of direct sunlight with mirrors to achieve high temperatures
- Provision of electricity (turbine cycle), process heat, desalination
- Cost effective **thermal storage** option
- **Grid stabilizing** effect thanks to turbine
- CSP uses only **direct component** of solar irradiation (=> soiling impact higher as in PV)

Images property of: Torresol energy, MASEN, SolarPACES, [T]

Comparison of soiling PV - CSP



- CSP soiling rate approx. **8-9 times higher** than PV (0.35%/d and 0.04%/d)
- Assumption: same surface densities on both technologies



Soiling on a more global scale?

- Direct measurement of soiling is expensive and time consuming
- Project developers require more global data for site selection

Questions:

- Is it possible to derive a soiling model and validate it with local measurement data?
- Can this model be transferred to a more global scale?



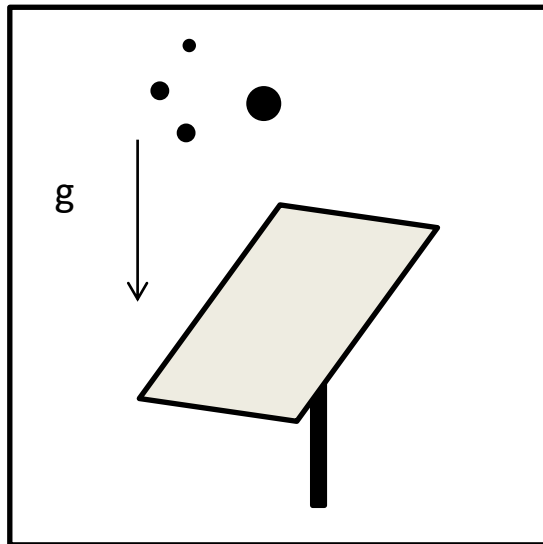
Measurement sites used in this study



Soiling model

Aim: predict soiling rate on solar mirrors from other weather data.
Test and validate with measurement data

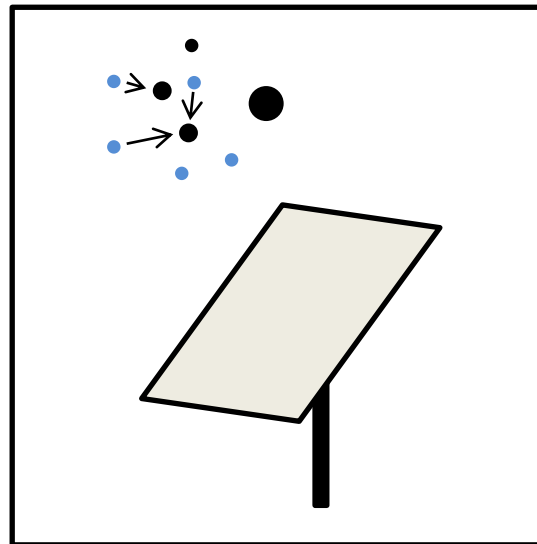
Sedimentation



➤ Gravitation

$$v_{S,p} = \frac{g d_p^2 (\rho_{Aerosol} - \rho_{Luft})}{18 \eta_{Luft}}$$

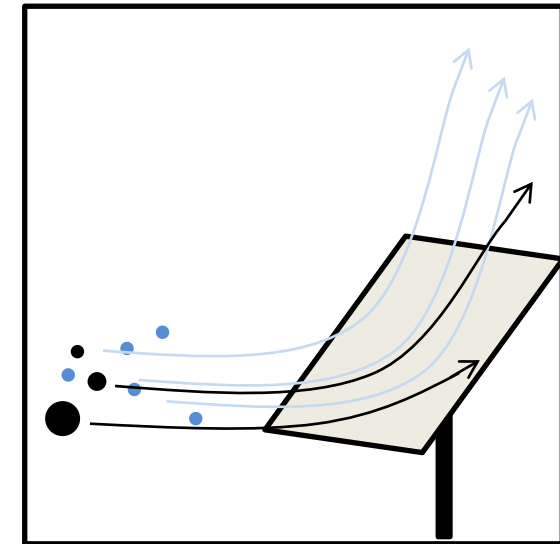
Brownian motion



➤ Thermal motion

$$v_B = a_{Brown} u_{Wind} \left(\frac{\nu_{Luft}}{D_B} \right)^{-\gamma}$$

Impaction



➤ Air stream/wind

$$v_{Im} = a_{Im} \cdot \frac{\sigma_{Ausrichtung} u_{Wind}}{1 + \exp(-f_{Im} \cdot (St - 1))}$$

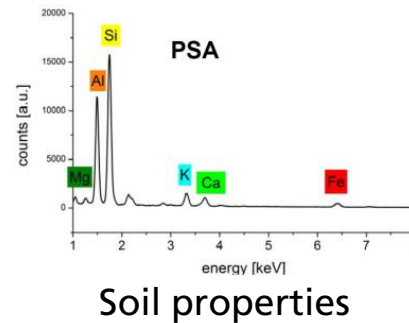
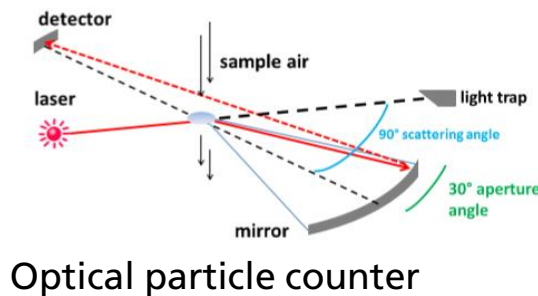
Also considered:

Rebound, resuspension, rain washing, cementation, mirror/panel orientation



Soiling model: input data

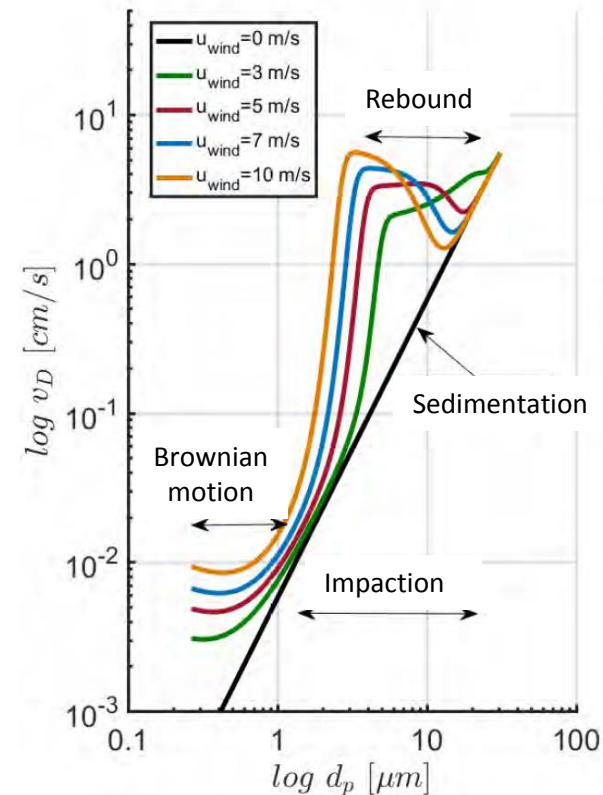
- Model is trained with a long term measurement dataset from PSA containing:
 - Aerosol particle number concentration from $0.25\ \mu\text{m}$ - $30\ \mu\text{m}$
 - Wind, relative Humidity, rain, irradiance, dew, temperature, atmospheric pressure, etc.



Flysand



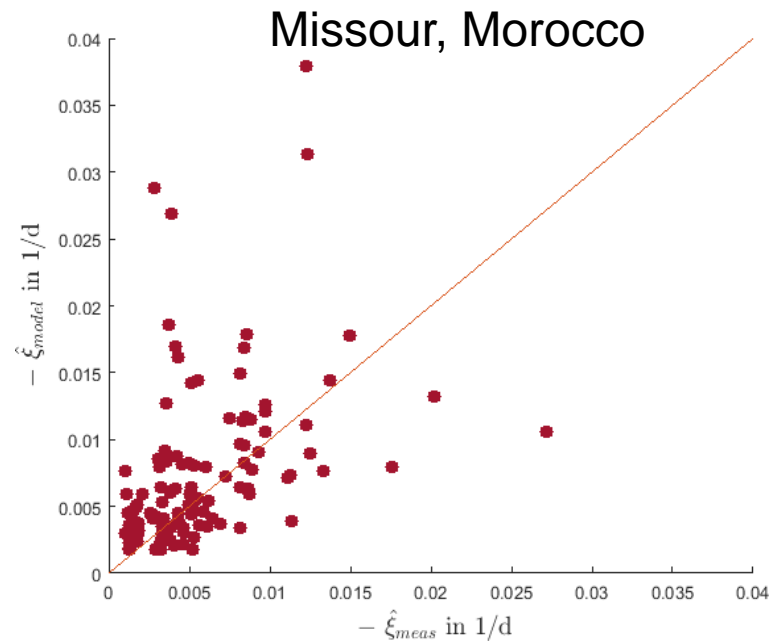
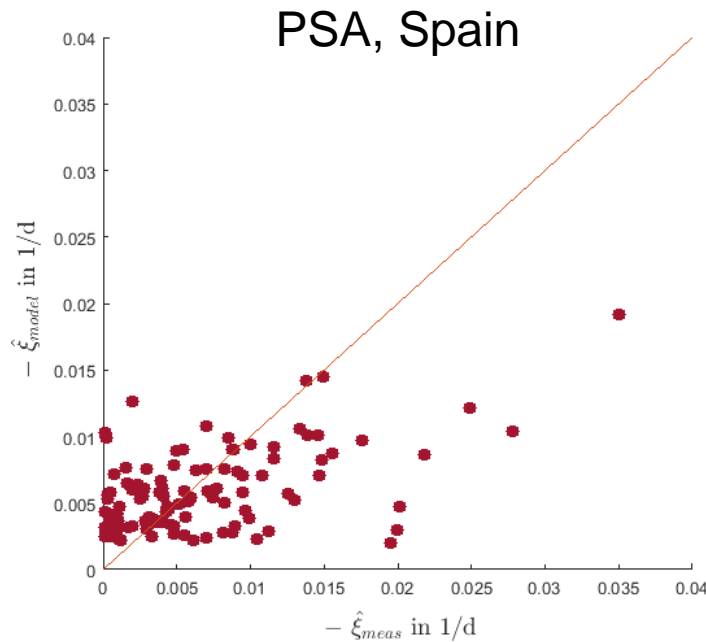
3D Wind, rain, temperature



Soiling model performance

- Model validated for two sites
- RMSE = 2 x soiling rate measurement accuracy
- Bias = 0.5 x soiling rate measurement accuracy
- Heavy soiling days (>1% daily loss) can be identified with 90% accuracy

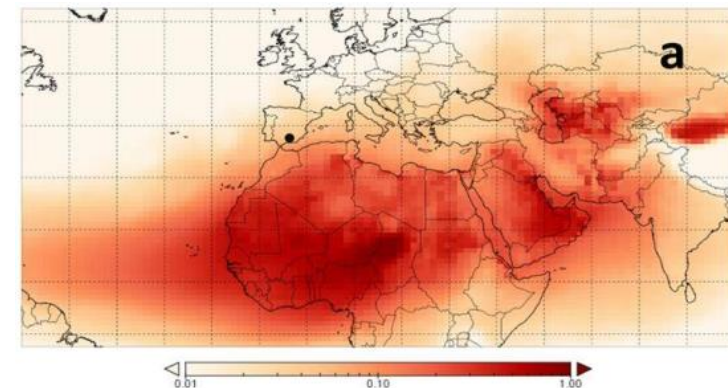
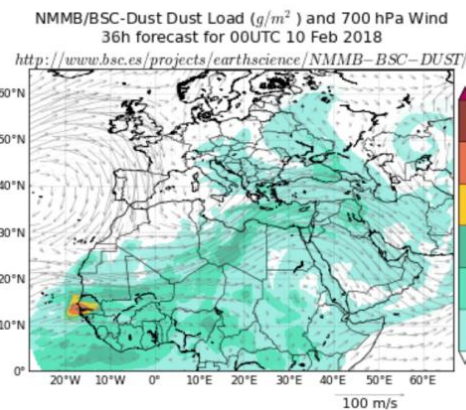
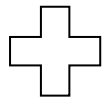
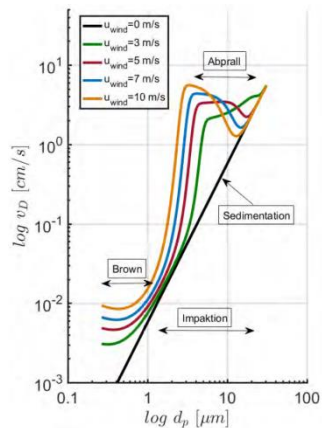
	Bias (\cdot %/d)	RMSE (%/d)
PSA Training Set	0.08	0.43
PSA Test Set	0.11	0.44
Missour	0.09	0.46



Outlook: Soiling rate map and forecast

Activities within the solwatt project (<https://solwatt.eu/>) in collaboration with BSC:

- Couple the CSP soiling model with BSC atmospheric dust transport model
 - => soiling rate forecast of 72 hours
 - => soiling rate map from reanalysis of historical dust model data
- Not yet covered: Transfer of CSP soiling to PV soiling possible?



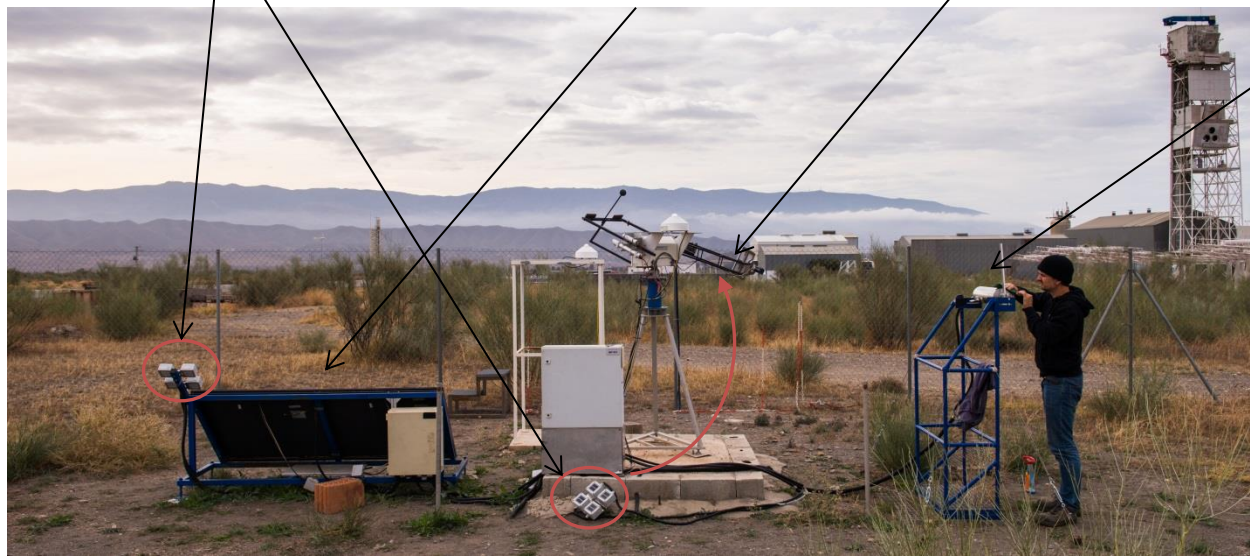
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Soiling measurement setup at PSA

PV reference cells PV panels SCC comparison TraCS for 4 mirrors transmission measurement (tubes)



PV panels

TraCS for 4 mirrors



rain

Optical particle counter

visibility

wind

